Geodiversity and the interactions of socio-natural systems in an Anthropocene perspective

Ricardo Galeno Fraga de Araújo Pereira
Geosciences Institute, Federal University of Bahia

Abstract

Earth Sciences´ investigations allow us to know that the planet Earth has an age of 4,6 billion years. During this elapsed time many processes changed radically some aspects of the planet. In the first four billions of Earth´s history, life was in its initial stages and was restricted to the ocean bodies. In the other remaining 500 millions of years, living organisms became more diversified, occupied the continental lands and the human society started to participate in the Earth System at about 12.000 years ago, although our species were already present at the planet for at about 200 thousand years. This means that human's presence in the planet is just a small fraction of the Earth´s history. But, on the other hand, human's modern lifestyle caused critical changes in this system, what led some scientific currents to say that we are responsible for the global warming. Beside this, the International Commission on Stratigraphy - ICS, which is the scientific body that sets the global standard for the time scale that expresses the history of the Earth, has a working group that is nowadays discussing the establishment of a new geological epoch known as Anthropocene. This new geological epoch is marked by substantial changes, in part irreversible, to the Earth System that are comparable to or greater in magnitude to other natural phenomena or processes that occurred previously in the planet, such as glaciers and volcanic activity. Will be discussed here the interactions between human societies and the geodiversity elements, which includes minerals, rocks, soils and reliefs, throughout the human history, focusing on the needs of resources to sustain the modern urban life and the myriad of limits, values and services of natural systems and their abiotic elements. Some examples will be presented, including the reality and conflicts of the geodiversity use in Chapada Diamantina, an ancient diamond mining region in the Northeast of Brazil.

1. Introduction

The history of the Earth is a subject that is in the scope of Geology. All the knowledge accumulated until the present let us believe that the planet has 4,6 billion years. We also know that most of the chemical elements are combined in the solid state as minerals, which in turn are the constituents of rocks, and both together are the basis of the Earth´s crust and of its geodiversity.

In this long-term history, the planet was submitted to many changes, such as the heat decay in its interior, crustal thickening, changes in the atmosphere composition and climate. Many questions still remain without a convincing answer, such as the origin of life. But, for instance, it is known that when the first living creatures started to make photosynthesis, they were responsible for significant changes in the atmosphere composition, that was enriched in Oxygen and caused the extinction of the primary forms of life.

The Geological time scale, defined by the International Commission on Stratigraphy – ICS (www.stratigraphy.org), establish all the subdivisions that express the global standards for the Earth history. The diversification and spread of life in the planet marks an important transition, separating the Phanerozoic Eon, that initiated at about 541 millions of years ago, from the Precambrian Eons known as: Proterozoic, Archean and Hadean, when the Earth inhabitants were not so complex and lived just in the oceans (Figure 1).

Nowadays the ICS is debating a new subdivision of the Quaternary period, which was initiated at about 2,5 millions of years ago and is marked by climate and sea level changes, in a new epoch named as the "Anthropocene". The Anthropocene Working Group - AWG advocates that the changes made by the humans in the planet are in a global scale and are comparable with natural processes that operates at the Earth´s system (Zalasiewicz *et al.*, 2017). Although the presence of our society in the planet is a brief event, the changes that we caused on its surface are notable at different scales and subject to many scientific debate, which also includes the debate about the climate changes (IPCC, 2014).

Human societies are dependent on geodiversity elements and services. In the beginning we used

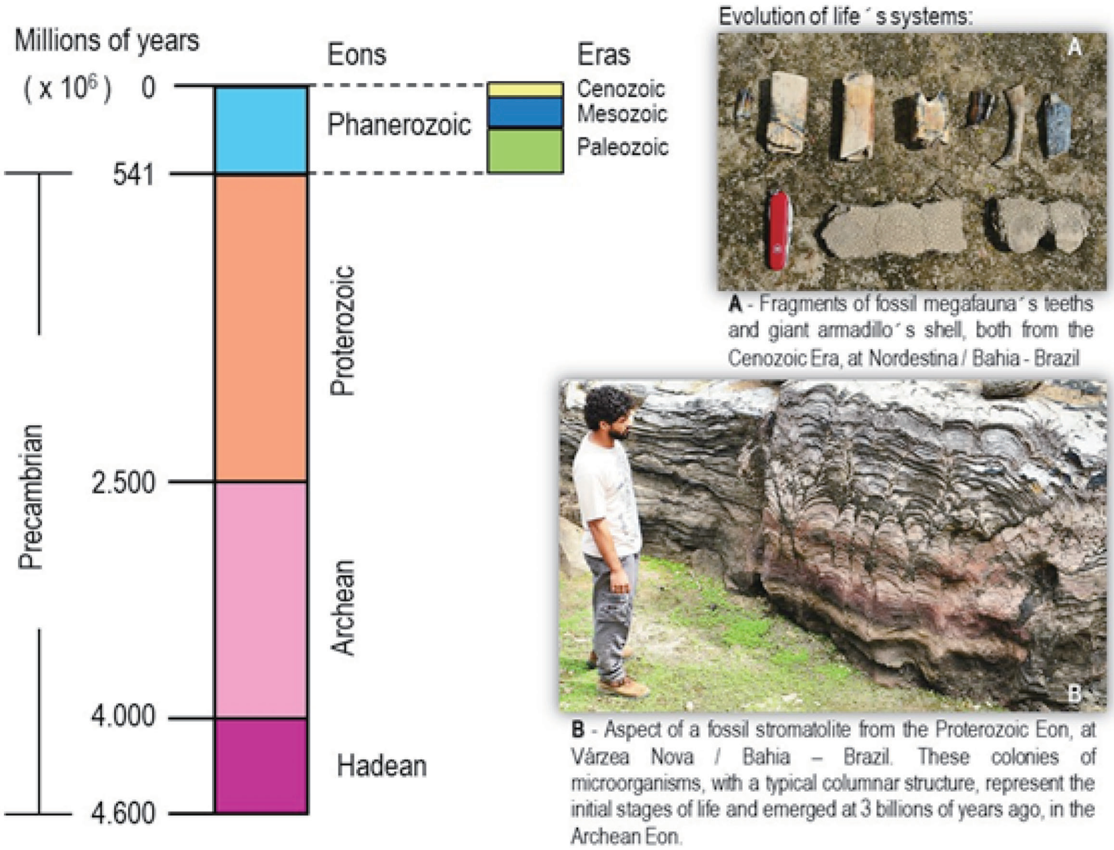

Figure 1: Summary of the Geological Time Scale, pointing the major divisions proposed by Cohen *et al*. (2013) and examples of the evolution of the life´s systems, showing fossils of microbialites, representing the initial stages of life in the planet, and fragments of fossils from the extinguished megafauna from the Cenozoic. It illustrates the advances of life forms, from micro-organisms to the megafauna, that can be found throughout the geological record.

stones to make tools, which allowed humans to hunt other species. Later, humans gained the ability to use metals to make weapons and dominate territories or use fossil fuels to make possible our mobility around the world. The use of the nature´s abiotic elements is in the basis of human history and evolution. But, despite this, for a long time the efforts towards nature´s conservancy were focused on the biodiversity elements, regarding the abiotic elements with a minor role. Looking at the future, it becomes necessary to develop a holistic and responsible view towards human ways of living, for example in cities, and nature´s conservancy. Human survival and the maintenance of human life quality depends on the ecosystem services, provided by the natural elements, and humans' ability to impact the Earth´s Systems in a planet scale.

2. Geodiversity and the interactions of socio-natural systems

Geodiversity elements includes the natural materials of the Earth Crust (ex.: minerals - Fig. 2A, rocks – Fig. 2B, soil and sediments), the processes that occur in the interior of the planet (ex.: convection currents, magmatism – Fig. 2C and metamorphism) and at its surface (ex.: weathering, erosion – Fig. 2D, hydrological cycle) resulting in the substrate, features and environments that people daily see, use and deal with. One must also point out that through this long-term history, the planet's evolution has produced environments far different from the ones known nowadays, resulting in some unique ancient products and materials.

Gray (2017) states that the word and concept of 'geodiversity' were first introduced in 1993, shortly after the Convention on Biological Diversity was agreed at the Rio Earth Summit in 1992. This author also defines it as 'the natural range (diversity) of geological (rocks, minerals, fossils), geomorphological (landforms, topography, physical processes), soil and hydrological features. It includes their assemblages, structures, systems and contributions to landscapes'.

This means that the geodiversity elements comprise not only the natural raw materials used in the daily life around the world, but also the space where human activities take place. If so, it is possible to say that these elements possess varied types of values, much beyond the economic value, which can include cultural, functional, aesthetical, scientific,

Figure 2- A: Stalactites formed by the precipitation of Calcium Carbonate, as cave minerals at Toca da Boa Vista Cave - Campo Formoso / Bahia – Brazil, the longest cave at South America. B: Sedimentary rocks, from the Paleozoic Era (from 252 to 541 million years before the present) at the Serra da Capivara National Park, Piauí/Brazil. C: Laguna Colorada, formed by hydrothermal volcanic activity at the Eduardo Avaroa Reserve – Uyuni / Potosi - Bolivia. D: Cliffs formed by natural coastal erosion processes at the Tambaba beach - Conde / Paraíba – Brazil.

ecological and even intrinsic values. Some of these values can be exemplified in other relief features, names of cities related with geographical aspects and protected areas due to its ecological relevance. Sharples (2002) adverts that the direct values of geological, landform and soil systems to humans are the reasons most frequently cited to justify the conservation of part of the geodiversity elements, albeit not the only reasons to it, as they play many other important roles in natural environments.

Sharples (2002) also points that there is a widespread misconception, which still prevails amongst some land managers, that rocks and landforms are mostly robust, so that any special management of their values is unnecessary. Whilst this is true for some elements or features, there are many aspects of geodiversity which are highly sensitive to disturbance. For example, taking into consideration the hydrological cycle and the installation of cities in a territory, it is possible to realize how critical this misconception is and how the hydrological crisis is a reality in many places around the world (Sivakumar, 2011).

Considering the 'Ecosystem Services' approach, which include the services of: Provisioning, Regulation & Maintenance, and Cultural (Haines-Young & Potschin, 2013), it also would be possible to extend these services concept to the geodiversity elements. Taking this into consideration, Gray (2017) refers to the 'abiotic ecosystem services' or 'geosystem services' and proposes the services discussed below for the geodiversity elements:

- ✓ Regulating services - include many terrestrial cycles (Figure 3A) including the carbon, nitrogen, phosphorus and sulphur cycles as well as the rock and hydrological cycles. Also included here are geomorphological processes, that help us to understand and mitigate the natural hazards facing society and which act to regulate environmental systems.
- ✓ Supporting services - include soil-forming processes, habitat provision (Figure 3B), the land as a platform for human activities, for human burial and disposal of waste, for storage of resources including water, oil and gas and for the potential of Carbon capture and storage.
- ✓ Provisioning services - involve freshwater, mineral and renewable energy sources (Figure 3C), a wide range of construction materials, as well as industrial and metallic minerals including gold and silver. It is no exaggera-

tion to say that modern society could not exist without these geological resources.

- ✓ Cultural services - include the mental and physical benefits of being in natural environments, geotourism and leisure pursuits, historical and spiritual associations (Figure 3D) related to geological environments and artistic inspiration.
- ✓ Knowledge services - include the ability to reconstruct past environments and the evolution of life using geological evidence, environmental monitoring, education (Figure 3E) and geoforensics based on the potential to use the diverse characteristics of soils and sediments to link suspects to crime scenes.

3. Socio-technical transitions: geodiversity and geosocial moments

Velho (2006) discusses about the relations between humans and the geodiversity´s raw materials, separating the evolution of the human civilization in five geo-social moments, when the use of new Earth materials caused significant impacts in the way of living and in the establishment of future so-

Figure 3- A: Soil formatting processes involve many different cycles, such as the Carbon, Nitrogen and Phosphorus cycles as well as the rock and the geomorphological cycle (Mucugê/BA – Brazil). B: The land as a platform for human activities, including the habitat provision, is a relevant role of the geodiversity (Rio de Janeiro/RJ – Brazil). C: The provisioning of freshwater and renewable energy are important assets of nature´s abiotic elements to our societies (Sobradinho/BA – Brazil). D: Many relief features have cultural and spiritual relevance for different societies around the world (Bom Jesus da Lapa/BA – Brazil). E: The knowledge contained in outcrops and other Earth features can enable present and future societies to understand Earth history and the discovering of new mineral resources (alluvial fan outcrop in Conde/BA – Brazil).

cieties. Taking this into consideration, this author separated the evolution of civilizations as pointed below:

- ✓ First geo-social moment – with the control and use of fire, at about 1,5 million years ago, the hominids were able to improve their life quality, due to the creation of new materials such as the ceramics (9.000 B.C.) and metal alloys (6.000 B.C.). Velho (2006) says that at 11.000 years ago, at the end of the last glacial period, humans had already occupied the entire planet and were at the same technological stone age. After this period the differences had arisen at different continents and the domination of the metal alloys and weapons allowed for a supremacy of some populations above others.
- ✓ Second geo-social moment – the use of gold as currency marks another important change in the evolution of human´s civilizations. According to Velho (2006) this use was initiated at about 700 B.C. at Sarts, the capital of Lydia and located at the Anatolia Region (Asia Minor).
- ✓ Third geo-social moment – the population growth and the technological improvement registered at 18th century marks the birth of industrial cities, with the increasing use of energy and raw material consumptions, demanding the use of coal as the basis for industrial societies.
- ✓ Fourth geo-social moment – the commercial use of petroleum as an energetic resource and in the material industry marks a relevant shift in human's society, as it allowed a technological revolution and supported the emergence of a society marked by high consumption habits, supported by a variety of products obtained from this element of the geodiversity. Velho (2006) states that this industry started at August 1859, when was demonstrated, at the state of Pennsylvania in the United State of America – U.S.A., that petroleum could be obtained with drilling wells.
- ✓ Fifth geo-social moment – marked by the use of Uranium as a nuclear energetic source, which took place at the 20th century. Nowadays, Uranium represents an increasingly relevant energy source in several parts of the world, as an alternative for the oil and gas exploration.

In the hyper-connected contemporary society, the wide range of use of computational systems, made of silicon components, to control many aspects and activities of our lives could be considered as a new geo-social moment, as these have greatly interfered in our daily life in a global scale, and is based in a mineral substance that, by the way, is the most abundant component of the Earth´s crust.

Although, Velho (2006) states that the next geo-social moment will also be related with the energetic sources and believes that the use of renewable sources, such as winds, solar heat and /or tides will play an important role at a local scale. In a global scale this author believes that the controlled use of Hydrogen will provide an important shift. The author also mentions that this next geo-social moment will be related with the industrial rocks and minerals, as its consumption increases in an exponential scale and demands high quality materials.

This increased consumption of Earth´s material and services, beside the changes that humans are promoting in the planet´s natural processes are the basis for the new debate in the Earth Sciences advocating the dawn of a new epoch of Earth´s history which is known as Anthropocene, when a new stewardship of geodiversity elements will become necessary (Steffen *et al*., 2011).

4. Geosystemic transformations and the anthropocene

The geological time scale (Figure 4) encompasses a time span of 4,6 billion years. If we consider that a human being can live for a maximum of 100 years, it is possible to observe that the span of a human life is insignificant compared to the time represented in this scale. But it is also possible to consider the existence of the human species, in particular the *Homo sapiens*, that inhabited Africa since about 200.000 years ago (Harari, 2012). Even at the human species timescale, the human presence in this planet is numerically insignificant in a time range. In both cases, this explains why it is usually difficult to visualize or get acquainted to many of the geological processes that take place slowly and continuously at the Earth´s surface.

Sometimes, this lack of awareness in some projects around the world is one of the reasons that explains why governments, decision makers or stakeholders tend to ignore the variability of the time span, caractheristic of some natural geological processes, when dealing with the Earth Systems. An example of this misconception is illustrated by

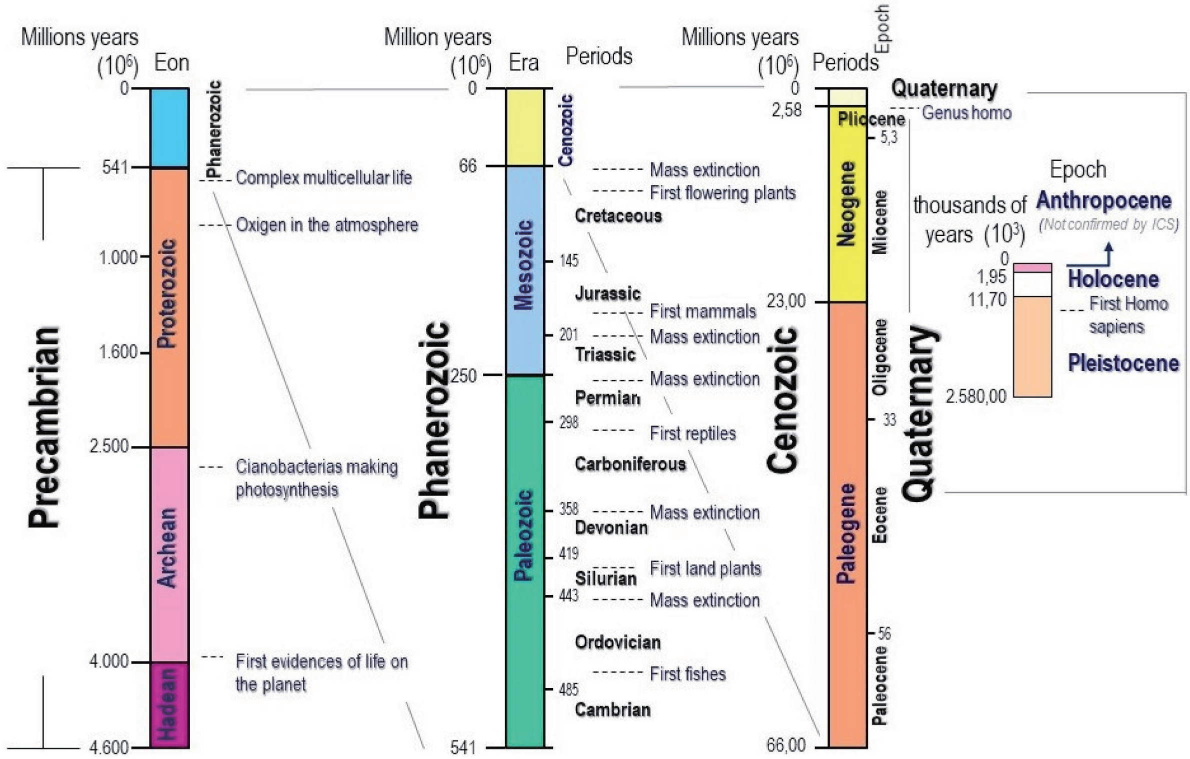

Figure 4: Geological Time Scale assuming the Anthropocene Epoch, as proposed by Zalasiewicz *et al*. (2017). The dates considered on the figure were based on the ages proposed by Cohen *et al*. (2013) and the listed events based on Teixeira *et al*. (2009).

the water crisis that took place, during the years of 2014 and 2015, in the Metropolitan Region of São Paulo - MRSP, the major city of Brazil, which detains one of the largest Water Production Systems in the world, covering 12 municipalities and producing about 33.000 liters of water per second (Soriano *et al.*, 2015).

As discussed by Soriano *et al.* (2015) the historic drought in southeastern Brazil in 2014-2015, began in São Paulo in October 2013. The consequences of this lack of rainfall, coupled with poor planning and irregular human occupation of the springs have resulted in a severe reduction of the service capacity of the main water supply system. This system counts with a minimum amount of precipitation, that greatly depends on the occurrence of a natural process. This is also part of the geodiversity and relates to the hydrological cycle, with uncertain rainfall frequency and volumes, for specific periods. Considering the historical average rainfall, the monthly measurements represent an average of a certain period, that usually is of thirty years. Thus, it is possible to foresee some expected rainfall values, but there is no guarantee neither for rain occurrence, nor for the certainty of specific values, or determined period. In the case of Sao Paulo's drought, authorities neglected the natural variations of the rainfall, along time, and the possibility of the occurrence of a drought, beside the lack of attention to changes in patterns of soil use, including disorderly occupation.

Steffen *et al.* (2011) says that, in the 21st century, there is a scarcity in critical resources, degradation of ecosystem services and the erosion of the planet's capability to absorb human waste. These authors call the attention for the speed and scale of this situation, which is fast and reaches a global scale, threatening the resilience of the Earth System. Because of this, the advent of the Anthropence -- the time interval in which human activities have reached an impact in terms of the global geological phenomena -- suggests the need to fundamentally alter the relationship between humans and the planet we inhabit. This becomes even more relevant as the evidences have emerged to show the uncertain capacity of the planet to provide the same accommodating environment that has facilitated human development, over the past 10.000 years.

The abovementioned authors place the evolution of the human enterprise in the context of a much longer Earth history and advocate for a human-inclusive Earth System, which implies that the global scale social and economic processes are now becoming significant features in the functioning of the System, of similar relevance of, e.g., atmospheric and oceanic circulation. Taking this into account, it is possible to say that humans are part of a system that is apart of the natural ones. This is in accordance with what was stated by Claude Lévi Strauss (1976), when he says that since hominids were able to transmit rituals and culture for the next generations, a social system was created. These hominids became not only a biological being, submitted to natural systems, but also social individuals. For this author, when it became culturally established that humans should not reproduce with each ones parents or relatives, an artificial condition has been created as a shifting point of relation to nature and the human submission to natural processes.

Harari (2012) points that the first hominids appeared at the Earth System at 2,5 million years ago. At this time our ancestors, wich formed the genus homo, were already able to make tools, using stones and / or bones. The genus originated different species, which shared or disputed space at the planet, during a timespan of between 2 million and 10 thousand years ago. Although the *homo sapiens* appeared before, it is believed that they left the african continent at about 70 thousand years ago and became the only *homo* species living on the planet in the last 10 thousand years. But, since 12 thousand years ago the *homo sapiens* started to live in societies and promote changes in a wide scale. As an example, Diamond (1997) shows evidences that the extinction of the mega-fauna of the American continent, at 11 thousand years ago, was due to hunting by the ancient inhabitants of America.

If we assume that human actions on Earth´s surface is truly resulting in long-term and wide scale changes of the dynamics and processes in course on Earth System, it becomes valid to point out when these changes started to be significant and reached a global scale. Zalasiewicz *et al.* (2017) present a dataset that provide robust evidences for the establishment of the onset for the Anthropocene at mid-20th century. Such data includes the increase in anthropogenic halocarbons and radionuclides (239+240Pu), also observed in the abundance of greenhouse gases at the atmosphere. About the Radionuclides, these authors highlight that they were derived primarily from nuclear weapons tests, showing an increase after 1950, that was followed by a marked decrease during the decades of 1960s and 1970s. They also point that the presence of microplastics in samples from the distal or slowly-accumulating deep marine oozes, is an imprint and recognizable stratigraphical evidence of the Anthropocene.

Therefore, it is possible to believe that in the same way that humans create new social rules, humans have also been able to create new kinds of environments, that are related to artificial processes, such as: industries (Figure 5A), mines (Figure 5B), pasture (Figure 5C) and cities (Figure 5D). These could be named as anthropocenic environments and in such places a huge amount of materials is processed in a short time span, overwhelming the capacity of the Earth natural systems to reach a natural balance. In each of these environments we will face situations that must be managed -- such as wastes and effluents to be treated, discarded or reused; or floods and / or erosion -- that must count with an adequate infrastructure to be avoided, including measures against the risk of desertification, due to deforestation and episodic rainfall that can remove the organic soil. These places create artificial conditions to support an increased amount of population, which will demand an increase of the 'Ecosystem Services' from the geodiversity, that sometimes cannot be supported in a natural scale, reaching a limit for the artificial - urban or regional - system or even for the natural system.

As dynamic systems, the Earth Systems are submitted to many changes. Since the emergence of life in the Archean Eon (between 3.850 to 2.500 million years before the present - Figure 4), most of the processes that take place above the crust and the environmental conditions have been modified. As these organisms were photosynthesizers, the composition of the atmosphere became enriched in Oxygen, what caused the deposition of iron ores in the oceans (Teixeira *et al*., 2009). Nowadays, as humans promote changes in the natural mass balance of the Earth, a new equilibrium must be reached. The Anthropocene just testifies that the humankind is a new geological agent. When we recognize that we are able of changes in the scale of the Earth System, we will be able to investigate the environmental conditions that future generations will need to deal with.

5. Anthropogenic changes and geodiversity in the landscape of Chapada Diamantina - Brazil

Chapada Diamantina is a region located in the central part of the Bahia state (Figure 6), in the northeast region of Brazil, that comprises highlands sculpted in sedimentary rocks from the Proterozoic Eon and occupies an area of about 65.000 km^2. Its history is marked by the ancient mining activity of

Figure 5- A: Petrochemical complex in Camaçari / Bahia – Brazil, one of the biggest at South America. B: Silver mine of Potosí / Bolivia, which was the main silver production area in the Spanish colonies and operates since the 16th century. C: Pasture in the countryside of the State of Bahia / Brazil. Nowadays the country holds one of the main positions in the meat production in the world. D: The city of Salvador, capital of the state of Bahia, was the main harbor of the southern hemisphere until the 18th century. Nowadays, with almost 3 million inhabitants, it is the fourth largest city in population numbers in the brazilian scenario.

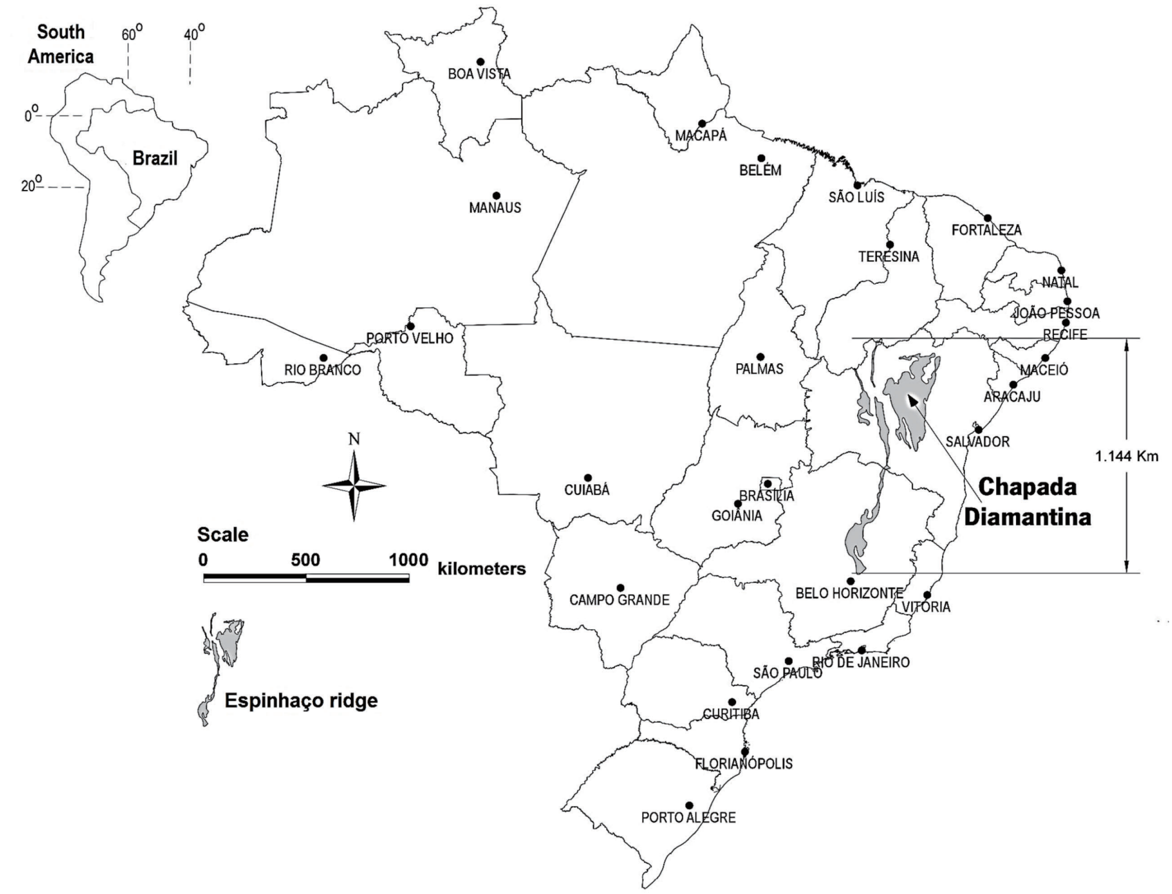

Figure 6: Location of the Chapada Diamantina region in the Brazilian context. It represents the northernmost part of the Espinhaço ridge, which extends in the North/South direction, for about 1.200 kilometers, at the oriental portion of the country.

gold and diamonds that drove its initial colonization during the 19th century, during the Brazilian colonial times.

Its mining potential was initially pointed out by the naturalists Spix & Martius, during their trip in Brazil between 1817 and 1820 (Spix & Martius, 1976). According to Teixeira *et al.* (2005) Diamonds were found at this region in 1844, at the place where nowadays is located the city of Mucugê. This discovery intensified the migration for that region and was responsible for the establishment of the main settlements existing at Chapada Diamantina. At 1867, when diamonds ores were found at South Africa, the price of this mineral fell and Brazil lost the international hegemony in the trade of diamonds, what caused the decay of the mining activity and the decadence of most cities at this region.

With the building of London´s subway and the Panama Canal, at the end of the 19th century, there was an international demand for abrasive materials. At this time, the black Diamond locally called as *carbonado* and without value as a gem, started to be used in the drills, resulting in another stimulus for the mining activity, that lasted until the first decade of the 20th century. Based on this, one can notice that this mining cycle spanned for about 60 years, when many cities thrived at the region (Teixeira *et al.*, 1998). But, with the Diamonds shortage, when its extraction was not available by employing the traditional methods, most of the population moved away, cities declined and just traces of the ancient prosperity were left on the territory. Nolasco (2002) estimated the populational variations for a group of main cities in the region, which is summarized in Figure 7.

The decline of the region lasted until the 1940s decade of the 20th century, when the second world war led to a rise in the demand of *carbonados* from the region, these were used in rock drillings and in the ignition of airplanes and submarines. After this cycle a new decline is registered and the recovery lasted until the 1970s decade, when new technologies began to be used in the mining of Diamonds, but at this time another cycle was about to begin in the region.

During the 1970s decade of the 20th century mechanical methods began to be applied on river channels and the mining activities started again. But at mid-80s the mining activity was forbidden by federal legislation, as the environmental awareness started to call attention and nature´s conservancy concerns started to be an important issue at the region, culminating in the creation of protected areas, including a national conservation park. Chapada Diamantina houses the springs of the major rivers of the state of Bahia, including the Paraguaçu river, which responds for almost 60% of the water supply for the metropolitan region of Salvador, the capital of the state.

With the creation of the protected areas a new economic cycle, based on tourism, started at Chapada Diamantina. The region represents today one of the main natural destinations for tourism in Brazil (Brito, 2005), receiving tourists from all over the world, that travel there to visit mainly sites related to its geodiversity, such as caves, waterfalls, hills and ruins of ancient mining activities (Figure 8). Although the visitors travel there due to its natural aspects, most of the landscape has been modified by the mining activity and the evidences of these activities can be found everywhere as tailings piles, dams, water channels and ruins. Nolasco (2002) describes the anthropogenic deposits and classify them as anthropocenic evidences of that territory.

Nowadays the region of Chapada Diamantina has a strong mining identity and counts with other economic activities, but the tourism plays an important role in the cities of Andaraí, Mucugê, Lençóis and Palmeiras, that were previously dedicated to the mining and trade of diamonds. In Mucugê, agriculture also represents an important income to the municipality. Mining activities took diamonds from the region and left poverty and significant environmental transformations, including deforestation, erosion and silting of rivers and springs. The geodiversity of Chapada Diamantina was the main asset that led to its occupation in the past, and is still the main aspect that enables touristic activities in the present.

6. Our future in common with the planet: reflections and alternatives to expand the lifespan of systems

Predict the lifespan of urban, regional and natural systems is such a great challenge, of similar scale to that of predicting the humankind extinction. Episodes of mass extinctions are part of the geological record since the beginning of the planet (Figure 4). Some of them are well explained, but some remain without convincing explanations. Looking at a dynamic system like the Earth System, sciences cannot ensure exactly how the future will be, but there is a possibility to build reasonable

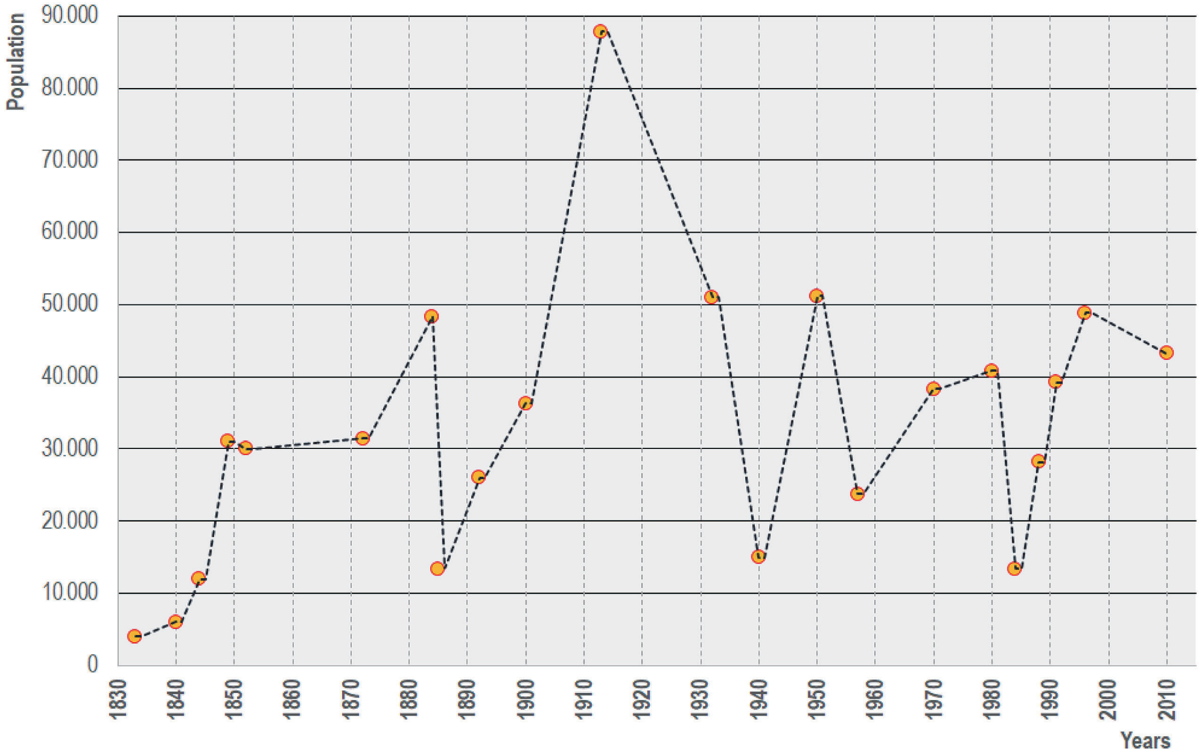

Figure 7: Historical estimated evolution of population in Chapada Diamantina, considering the data presented by Nolasco (2002) and the population for the major mining cities, namely: Andaraí, Mucugê, Lençóis e Palmeiras.

Figure 8: Ruins of houses at Xique Xique de Igatu, a district of the city of Andaraí that was an important mining village at the past, with about 4.000 inhabitants. Nowadays its population counts less than 500 inhabitants. The ruins, that are found evey-where at that district, testify the opulence of the past history. The white sandy river plain, in the back of the ruins, is a result of this ancient activity, when the sediments were washed to find the diamonds, resulting in the silting of most rivers.

scenarios and manage the social and economical processes needed to reach the best modeled ones.

Meadows *et al.* (1972) made a formal world model, attempting to bring together the large body of knowledge that was available until the 70th decade of the 20th century. This model considered the parameters of food, nonrenewable resources and pollution absorption, as well as, the growth and maintenance of population and industry, in the time span from the year 1900 to 2100. It also considered the cause-and-effect relationships among the five listed factors and analyzed how a change in one variable might ultimately affect each of the others.

At that time, the abovementioned authors concluded that the shortage in the doubling time of many of man's activities would bring the human society close to the limits of its growth surprisingly soon. Although they wanted to emphasize that the model just pointed general behaviors and not the numerical values, which were only approximately known, the curve for the population growth reaches its peak at the year of 2050, starting to decrease after it, mostly due to nonrenewable resource depletion. Nowadays, it is possible to consider that the present technological scenario is much different from previous ones, and many new materials and industrial processes have been created and used at the present, inputting new perspectives to this model and expanding the lifespan of urban and regional systems.

Almost 15 years later, the concept of sustainable development entered the global agenda. It was first ennounced in the UNESCO (1986) report, also entitled as "Our Common Future", which defined the sustainable development as the kind of development that meets the needs of the present human societies, without compromising the ability of future generations to meet their own needs. As is clear in this statement, this is an anthropocentric concept, relegating to the natural systems a minor role, neglecting Earth System´s intrinsical value, that is far relevant in a geological time perspective and more remarkable than solely being treated as a source of resources for our societiy´s needs.

The UNESCO´s (1986) report already considered that, by the turn of the 20th century, almost half of the world would live in urban areas – moving from small towns to huge megacities, and also that the economic growth would lead to improvements in living standards. This has also sometimes been achieved in ways that are globally damaging in the longer term, leading to unforeseen effects on the environment. The report also assumed that, at that time, the pressures on the planet were already unprecedented and were accelerating at rates and scales that were new to the human experience. In the other hand, the report believed that the new technologies and the potentially unlimited access to information constituted great promises. Based in such assumptions they concluded that our societies´ challenge to the future would lead to the shifting of the focus of attention to environmental policies in a world basis.

This global agenda is considering the cause-and-effect relationships -- that are intrinsic to Earth, as much as to urban and regional systems. It recommends the achievement of common and mutually supportive objectives, with aspirational goals for the world community that takes into account the interrelationships between people, resources and development, and is concerned with a long-term environmental perspective. This agenda can be considered a fortunate pact that resulted from the sustainable development concept, with positive impacts over geodiversity assets.

In an Anthropocene perspective we must recall the land ethics paradigm (Leopold, 1949) which considers the Earth System as a community to which we belong, and expands the definition of "community" to include not only humans, but all the other parts of this system, as well: soils, waters, plants, and animals, that this author called as "the land". We must also understand the sustainable development in its broadest sense, glimpsing that its strategy aims to promote harmony among human beings and between humanity and nature.

This broad view drives us to the geoparks strategy as one alternative -- among others in this Anthropocene perspective -- to foster local initiatives that can expand regional and natural systems´ lifespan, and which can be implemented in cities and / or territories that hold a geological heritage with regional or international relevance. UNESCO (2016) defines Geoparks as single geographical areas, where sites and landscapes of international geological significance are managed under a holistic concept, that merges protection, education and sustainable development. It uses its geological heritage, in connection with all other aspects of the area's natural and cultural heritage, to enhance awareness and understanding of key issues facing society.

Henriques & Brilha (2017) point that the implementation of targeted local projects with a global reach is a challenging task, but the mechanisms and actors usually involved in the creation of a geopark can be of great usefulness to conceive other action plans, fostering global understanding as a tool to achieve sustainable development goals.

In a global perspective, the Global Geopark Network -GGN is a legally constituted not-for-profit organization founded in 2004. It is a dynamic network where members are committed to work together, exchange ideas of best practice, and join in common projects to raise the quality standards of all products and practices of a UNESCO Global Geopark (http://www.globalgeopark.org/index.htm). Until May 2017, this network counted with 127 Geoparks in 35 Member States (Figure 9). If in one hand the Geoparks are an increasingly applied strategy in Europe and in the Asia – Pacific Region, in the other hand its growth in the Americas faces a rather slow rate.

The Japanese Geopark Network - JGN (http://geopark.jp/en/) comprehends a geopark as a single and unified geographical area, where people conserve important geological heritage and landscape, as well as utilize this Earth heritage for education, disaster mitigation activities and geotourism, all with the aim of reaching a sustainable development for local communities. This network is a specified non-profit organization which provides support and a networking platform for Japanese Geoparks and aspiring geoparks. The JGN consists of 8 UNESCO Global Geoparks, 35 National Geoparks and 14 aspiring geoparks listed as associate members. The network also has supporting members, both individuals and private companies that want to support geoparks.

Brazil counts with just one Geopark, namely Araripe Geopark (http://geoparkararipe.org.br/), which was the first geopark of the American continent and, since the year of 2006, represents the only case of successful geopark implementation in the country. As geoparks must be based on bottom up approaches, linked with local identities, this may be one of the reasons that the geopark projects spread in the country in such a slow rate. As pointed by many authors (Fausto, 2012; Schwarcz & Starling, 2015; Holanda, 1976), since colonial times the local and regional identities have not been encouraged in the country and national governments always chased all the initiatives that tried to foster local commitments. These authors also highlight that the building of a continental country is historically the focus of national policies in Brazil, at the expense of strengthening local identities.

Although the country has yet to develop a national geopark network, some local proposals are in course, driven by different kinds of initiatives. These can be promising emerging alternatives for the future of the Brazilian regional and natural systems, or even for some urban systems, fostering the citizenship and a holistic nature conservation policy, based in a land ethic perspective and more sustainable basis. As an example, it is worth to point the proposals for the creation of three geoparks lo-

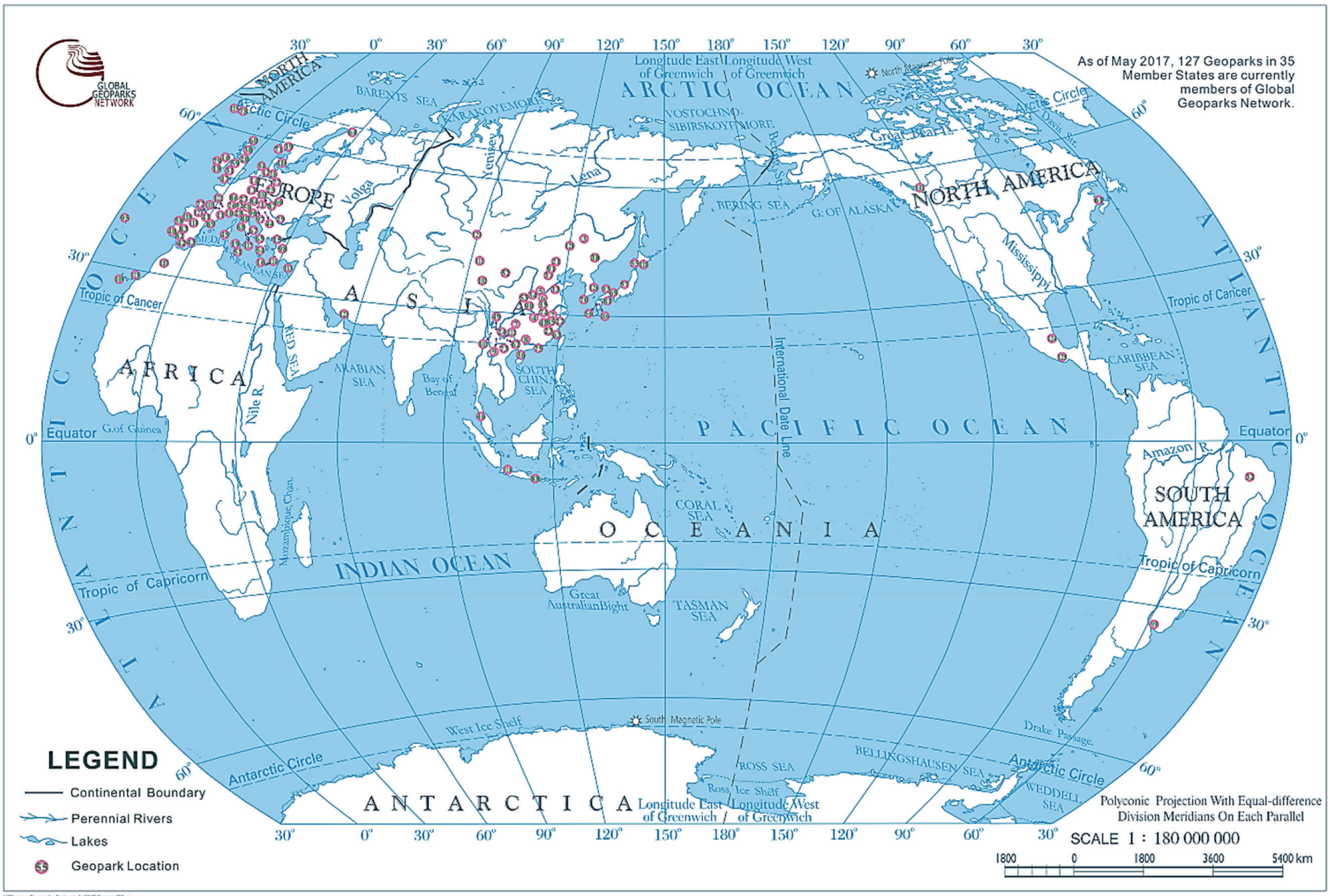

Figure 9: Distribution of Global Geoparks Network members. http://www.globalgeopark.org/homepageaux/tupai/6513.htm

cated at the region of Chapada Diamantina (Rocha & Pedreira, 2014; Pereira *et al.,* 2017, Martins *et al.,* 2017), which counts with relevant geodiversity assets and a historical unsustainable process of mineral exploitation, that took off valuable resources and left a poverty trail and / or demise in face of most of the urban systems at that region.

The socio-natural systems in Chapada Diamantina are marked and linked by a strong mining identity, due to its history, although this is not the main economical activity at most of the cities at that region nowadys. Tourism raise as a sustainable alternative, in cities that were the main urban systems during the ancient mining period. The legacy of this activity, alied with some geodiversity elements, are the touristic assets for localities that are marked by Anthropocene transformations of local natural systems. This cultural and geological heritage are the assets that motivated the local geoparks projects, and can be used in educational and geotourism activities, fostering locally the understanding of global dynamics in the Earth´s system, and globally testimoning the ability of social systems to fastly trasnform the natural systems, besides the need for long term planning to achieve the sustainability of urban and regional systems.

Geoscicences provide important informatons, tools and alternatives for a sustainable future, when a new stewardship of geodiversity elements will be critical to support and expand the lifespan of urban and regional systems. Geopark projects are one of these possible tools, which can be applied in local scale, but facing global challenges. Humans´history shows that transformations in the management and use of geodiversity assets are the paramount trigger for the shiftenning of geo-social moments, marked by technological advances and prosperity of human societies. Assume the Anthropocene epoch and the global scale transformations of Earth System by human societies, is an alternative paradigm that must be adopted by policy makers and consumers, to ensure better practices for our future in common with natural systems, reinforcing the role of Earth Sciences in the implementation of the Sustainable Development Goals, as a planetary agreement for social development in harmony with nature´s dynamic systems.

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